



**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**  
**BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES**

In re the application of:  
ARAVIND PADMANABHAN, ET AL.

Docket: H19-02237

Serial Number: 10/068,273

Group Art Unit: 1771

Filed: February 7, 2002

Examiner: Hai Vo

For: LIGHT EMITTING PHOTONIC CRYSTALS

**BRIEF FOR APPELLANTS**

Commissioner For Patents  
P.O.Box 1450  
Alexandria, Virginia 22313-1450

Sir:

This is an Appeal to the Board of Patent Appeals and Interferences from the Final Rejection of claims 1-17 and 45-49 mailed December 1, 2005 in the above identified case. A Notice of Appeal was filed is being filed herewith. An oral hearing is not requested.

This Brief is hereby filed in triplicate. The Commissioner is authorized to charge the required appeal brief fee of \$500.00 to Deposit Acct. No. 01-1125. In the event that the Commissioner determines that an additional extension of time is required in order for this submission to be time, it is requested that this submission include a petition for an additional extension for the required length of time and the Commissioner is authorized to charge any other fees necessitated by this paper to Deposit Acct. No. 01-1125.

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#### I. REAL PARTY IN INTEREST

The real party in interest is Honeywell International, Inc., which is the assignee of record.

#### II. RELATED APPEALS AND INTERFERENCES

With respect to other appeals or interferences that will directly affect, or be directly affected by, or have a bearing on the Board's decision in this appeal, please note that there are no other related applications on appeal or subject to an interference known to appellant, appellant's legal representative or the assignee.

#### III. STATUS OF CLAIMS

The claims in the application are 1-49. Claims 1-17 and 45-49 are pending, stand rejected and are on appeal. Claims 18-44 have been withdrawn from consideration. No claims are allowed.

#### IV. STATUS OF AMENDMENTS

An amendment was filed after final rejection on February 21, 2005. An Advisory Action was mailed on March 11, 2005 which indicated that the amendment would be entered upon filing of this Brief on Appeal, however, the amendments did not overcome the rejections. The claims in the Appendix reflect these amendments.

#### V. SUMMARY OF THE INVENTION

The present invention claims a light emitting or light transmitting photonic crystal which comprises a *two dimensionally periodic or three dimensionally periodic* microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members having voids between adjacent members, and said *members additionally having randomly nanoporous surface porosity* and which photonic crystal has a

photoluminescence property. The inventive material shows enhanced and spectrally controlled, tunable photoluminescence and electroluminescence and finds use as high-luminosity light emitting diodes (LEDs), wavelength division multiplexors, high-active-area catalyst supports, photonic bandgap lasers, silicon-based UV detectors, displays, gas sensors, and the like. The invention also provides a structure comprising the light emitting or light transmitting photonic crystal positioned on a surface of a substrate and a photonic device produced therefrom.

Such photonic crystals are actively emitting photonic materials, with superimposed nanoporosity being responsible for the emission of light, and the periodicity of the underlying microstructure controlling the propagation of the emitted photons. Prior art porous silica devices suffer from non-uniform pore size distribution and limited active surface area. These problems result in lowered photoluminescence intensity and considerable variability in this intensity from device to device. Compared to conventional porous silicon, the inventive material has much larger active surface area since the whole volume of the material is used in the process for creating nanoporosity. The nanoporosity is superimposed after the periodic microporosity has been created. Thus, the photoluminescence in these structures is enhanced by about ten-fold over conventional porous. The invention has the advantages of porous silicon and silicon-based photonic crystals and produce light emitting photonic crystals that exhibit two-levels of porosity: *periodic* microporosity in an inverse opal backbone and superimposed *random nanoporosity* on the microporosity.

## VI. ISSUES

(a) Whether Claims 1-12, 15 and 16 are properly rejected under 35 U.S.C. 103 (a) over Zakhidov, et al (either WO 200221905 or U.S. 6,261,469) in view of Gole, et al (U.S. 6,589,883).

(b) Whether claims 13 and 14 are properly rejected under 35 U.S.C. 103(a) over Zakhidov et al. in view of Gole, et al and further in view of Russell et al. (U.S. patent 6,093,941).

(c) Whether claim 17 is properly rejected under 35 U.S.C. 103(a) over Zakhidov et al. in view of Gole, et al and further in view of Koops (U.S. patent 6,064,506).

(d) Whether claims 45, 46, 48 and 49 are properly rejected under 35 U.S.C. 103(a) over Zakhidov et al. in view of Gole, et al and further in view of Jewell (U.S. patent 5,617,445).

(e) Whether claim 47 is properly rejected under 35 U.S.C. 103(a) over Zakhidov et al. in view of Gole, et al , further in view of Jewell and further in view of Koyama et al. (U.S. patent 6,462,356).

## VII. GROUPING OF CLAIMS

The claims do not all stand or fall together, but only within the following groups:

I. Claims 1-12, 15 and 16.

II. Claims 13 and 14

III. Claim 17

IV. Claims 45, 46, 48 and 49

V. Claim 47

Separate arguments directed to each of these separate grouping of claims are provided below, and such corresponding to the rejections listed under ISSUES, above.

## VIII. ARGUMENTS

Claims 1-12, 15 and 16 stand rejected over Zakhidov, et al (either WO 200221905 or U.S. 6,261,469) in view of Gole, et al (U.S. 6,589,883). It is respectfully submitted that the rejection is not well taken. Applicants wish to point out that this invention is an improvement over Zakhidov, et al, and this application and the Zakhidov, et al reference are commonly owned and have two common co-inventors, namely Anvar Zakhidov, and Ray Baughman.

This invention pertains to a photonic crystal which has the following properties:

1. It is either light emitting or light transmitting;
2. The photonic crystal comprises a *two or three dimensionally periodic* microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members having voids between adjacent members; and
3. The members additionally have *random nanoporous surface porosity* superimposed on the periodic microporosity.

The nanoporosity is responsible for the emission of light, and the periodic macroporosity of the photonic crystal structure controls the propagation of emitted photons. Compared to conventional porous silicon, the inventive material has much larger active surface area since the whole volume of the material is used in the process for creating nanoporosity.

The nanoporosity is created on the surface after the *periodic* microporosity has been created. Thus, the photoluminescence in these silicon nanofoams is enhanced by about ten-fold over conventional porous silicon. In addition, by tuning the position of the photonic band gap of the photonic crystal structure, even further photoluminescence enhancement at particular wavelength bands of the photoluminescence spectrum may be achieved due to nonlinear effects at the photonic band gap edges. The invention provides very low density nanofoams, which are highly periodic (photon confinement in photonic bandgap) and have nanoscale porosity. The invention combines the advantages of porous silicon and silicon-based photonic crystals and can be used to produce light

emitting photonic crystals that exhibit two-levels of porosity: *periodic microporosity* in the silicon inverse opal backbone and *random nanoporosity* obtained by making the silicon backbone randomly nanoporous.

The examiner is correct that Zakhidov, et al. teaches a three dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members having voids between adjacent members. However, as the examiner agrees, Zakhidov, et al does not show nanopores superimposed on their periodic micropores. This invention improves over Zakhidov, et al because the inventive material shows enhanced and spectrally controlled, tunable photoluminescence and electroluminesce. Periodic photonic crystals confine and localize photons. According to this invention, such photonic crystals are actively emitting photonic materials, with the nanoporosity being responsible for the emission of light, and the *periodicity* of the photonic bandgap structure controlling the propagation of the emitted photons.

Zakhidov, et al. shows the underlying dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members, but *they do not show superimposed surface nanoporosity*.

Gole, et al shows a microporous structure with superimposed surface nanoporosity, which is not taught to be random, and *no periodic microporous structure*.

It is the position of the examiner that one could combine Zakhidov, et al. and Gole, et al to produce the instant invention. However, it is submitted that there is no suggestion from the art that one should combine Zakhidov, et al. and Gole, et al to superimpose surface nanoporosity on a periodic microporous structure. Even if such were combined, there is still no teaching of random nanoporosity.

Zakhidov, et al certainly show the underlying two or three dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented,

monodispersed members having voids between adjacent members. However, that is where the similarity ends. Nowhere is Zakhidov, et al do they even mention a that their microporous structural matrix additionally having random nanoporous surface porosity. Nowhere in Zakhidov, et al, do teach or suggest nanopores superimposed on micropores.

The claims also require that the instant structure be light emitting or light transmitting. The Zakhidov, et al materials are not necessarily light emitting or light transmitting. The examiner also *admits* that Zakhidov, et al does not teach photoluminescent (See Advisory Action). For example, diamond is not clearly a light emitting or light transmittal photonic crystal. Even if it were, this condition this is insufficient to meet the requirements of this invention. While one may intentionally transform their topographical structure, according to the techniques of the present invention, and make them into a light emitting or light transmitting photonic crystal, they are not inherently light emitting or light transmitting photonic crystals, nor are they taught to be such by following the teachings of Zakhidov, et al. Applicants' claims describe a light emitting or light transmitting photonic crystal having a randomly nanoporous surface porosity. In the embodiment closest to this invention, Zakhidov et al. at column 4, lines 52-57 teaches a carbon foam having an average pore diameter of about 4Å to about 10Å, which carbon foam is not a light emitting or light transmitting photonic crystal. The previously submitted declaration from Dr. Ray H. Baughman, a co-inventor of the present application and a co-inventor of the applied reference to Zakhidov, et al. declared of record that the carbon foam described at column 4, lines 52-57 of Zakhidov, et al. is not a light emitting or light transmitting photonic crystal which comprises a two dimensionally periodic or three dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members having voids between adjacent members, and said members additionally having randomly nanoporous surface porosity. It is pointed out that nowhere in U.S. patent 6,261,469 to Zakhidov is photoluminescence mentioned. It is therefore submitted that in view of the incorporation of a required photoluminescence property in the claims, and the Declaration of Dr. Baughman, which



is already of record, that the instant claims are not suggested by any combination of applied prior art.

In short, while Zakhidov, et al. shows a two dimensionally periodic or three dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members having voids between adjacent members, the structure is not necessarily light transmitting, and does not show or suggest superimposed nanoporosity. Gole, et al shows a microporous structure with superimposed surface nanoporosity, but *no periodic microporous structure; and no random nanoporosity*. It is submitted that there is no suggestion from the art that one should combine Zakhidov, et al. and Gole, et al to superimpose random surface nanoporosity on a *periodic* microporous structure. There is no suggestion from Zakhidov, et al. and Gole, et al, to produce random nanoporosity after the periodic microporosity has been created. There is no suggestion from Zakhidov, et al. and Gole, et al that photoluminescence in a *periodic* microporous structure would be enhanced by about ten-fold over a conventional porous structure. There is no suggestion from Zakhidov, et al. and Gole, et al that by tuning the position of the photonic band gap of a photonic crystal structure, even further photoluminescence enhancement at particular wavelength bands of the photoluminescence spectrum may be achieved due to nonlinear effects at the photonic band gap edges. Indeed, Zakhidov et al. goes no further than discussing steps for the removal of their material A from an A-B composite structure. Accordingly, the structure as described by Applicants is structurally different than any structure described by Zakhidov et al.

In summary, it is clear that Zakhidov et al. produce a two or three dimensionally *periodic* microporous structure which is not stated to be photoluminescent. It is clear that Gole, et al produce nanoporosity on microporosity which is not stated to be random. There is no suggestion that one *should* form *random* nanoporosity on a two or three dimensionally *periodic* microporous structure to obtain the benefits described in the specification. It is submitted that the examiner's position is merely a classic impermissible reconstruction of

the art in light of applicant's disclosure. There is no suggestion that Zakhidov et al. and Gole, et al should be combined, and if hypothetically combined, that the combination would produce the described benefits. For these reasons it is submitted that the rejection over Zakhidov, et al in view of Gole, et al should be reversed.

Claims 13 and 14 stand rejected under 35 U.S.C. 103(a) over Zakhidov et al. in view of Gole, et al and further in view of Russell et al. (U.S. patent 6,093,941). It is respectfully submitted that the rejection is not well taken. The arguments with regard to Zakhidov et al. and Gole, et al apply equally herein and are repeated from above. The Examiner has applied Russell et al. to show that a photonic band gap material can be deposited on a sapphire substrate. It is respectfully asserted that the combination with Russell et al fails to overcome the differences between Zakhidov et al. in view of Gole, et al, and the claimed invention.. The fact that Russell, et al show the formation of a light emitting photonic structure on a sapphire substrate does not imply that the instant structure having random nanoporosity on microporosity should be formed on a sapphire structure. More specifically, the combination of Zakhidov et al. in view of Gole, et al and Russell et al. still fails to teach or suggest a periodic microporous structure having superimposed randomly nanoporous surface porosity which is also capable of emitting and/or transmitting light. It is submitted that this rejection is a mere reconstruction of the art in light of applicant's disclosure. For these reasons, it is submitted that the rejection has been overcome and should be reversed.

Claim 17 stands rejected under 35 U.S.C. 103(a) over Zakhidov et al. in view of Gole, et al and further in view of Koops (U.S. patent 6,064,506). It is respectfully submitted that the rejection is not well taken. The arguments with regard to Zakhidov et al. in view of Gole, et al apply equally herein and are repeated from above. Koops teaches an optical multipath switch with electrically switchable photonic crystals. Koops forms miniaturized needles wherein cavities between the needles are filled with liquid crystal material. The Examiner has applied Koops to show that it would be obvious to have a liquid crystal material imbibed on the photonic crystal of the invention. However, similar to Russell et

al., the combination with Koops fails to overcome the differences between Zakhidov et al. in view of Gole, et al and the claimed invention. The fact that liquid crystal material can be imbibed between the Koops needles does not suggest that liquid crystal material can be imbibed in the instant structure having random nanoporosity on periodic microporosity. Furthermore, the combination of Zakhidov et al. in view of Gole, et al and Koops still fails to teach or suggest a periodic microporous structure having superimposed randomly nanoporous surface porosity which is also capable of emitting and/or transmitting light. For these reasons, it is submitted that the rejection should be reversed.

Claims 45, 46, 48 and 49 stand rejected under 35 U.S.C. 103(a) over Zakhidov et al. in view of Gole, et al and further in view of Jewell (U.S. patent 5,617,445). It is respectfully submitted that the rejection is not well taken. The arguments with regard to Zakhidov et al. in view of Gole, et al apply equally herein and are repeated from above. Jewell teaches a quantum cavity light emitting element having cavities and a light emitting material within the cavities. The Examiner has applied Jewell to show that it would be obvious to deposit a metal layer on opposite surfaces of a photonic crystal. The Examiner has also applied Jewell to show that it would be obvious to have a light emitter positioned to direct light onto the photonic crystal of the invention, and also to show that it would be obvious for such a light emitter to transmit light having the claimed wavelength range. However, the fact that a metal may be deposited on Jewell's structure does not imply that a metal can be applied onto the instant structure having random nanoporosity on periodic microporosity. Also, the fact that the Jewell structure has a light transmitter within a certain wavelength range does not imply the usefulness in the present context. Furthermore, similar to Russell et al. and Koops, it is respectfully asserted that the combination of Zakhidov et al. in view of Gole, et al with Jewell fails to overcome the differences between Zakhidov et al. in view of Gole, et al and the claimed invention. More specifically, the combination of Zakhidov et al. in view of Gole, et al and Jewell still fails to teach or suggest a periodic microporous structure having superimposed

randomly nanoporous surface porosity which is also capable of emitting and/or transmitting light. For these reasons, it is submitted that the rejection should be reversed.

Claim 47 stands rejected under 35 U.S.C. 103(a) over Zakhidov et al. in view of Gole, et al, further in view of Jewell and further in view of Koyama et al. (U.S. patent 6,462,356). It is respectfully submitted that the rejection has been overcome. The arguments with regard to Zakhidov et al. in view of Gole, et al and Jewell apply equally herein and are repeated from above. Koyama et al. teaches a light emitting device having a light emitting section and a waveguide section on a substrate, which waveguide section transmits light from the light emitting device section. The Examiner has applied Koyama et al. to show that it would be obvious to have an electrode attached to the electrically conductive, optically transparent layers of the claimed invention. However, the fact that these may find use in the Koyama, et al context does not imply usefulness in the context of this invention. Similar to Russell et al. and Koops, it is respectfully asserted that the combination of Zakhidov et al. in view of Gole, et al with Jewell and Koyama et al. fails to overcome the differences between Zakhidov et al. in view of Gole, et al and the claimed invention. More specifically, the combination of Zakhidov et al., in view of Gole, et al Jewell and Koyama et al. still fails to teach or suggest a periodic microporous structure having randomly superimposed nanoporous surface porosity which is also capable of emitting and/or transmitting light. For these reasons, it is submitted that the rejection has been overcome and should be reversed.

Appellants submit that the Examiner is looking beyond the teachings of the reference. The reference has to offer sufficient motivation for one skilled in the art to achieve the desired result. In the instant case, the motives in the references, as disclosed by the practices therein, are quite different from those in the instant invention. The present invention, therefore, is not made obvious by the combination the Examiner has suggested, and the 35 U.S.C. 103 rejections should, therefore, be overruled. "Obviousness cannot be established by combining the teachings of the prior art to produce the claimed invention, absent some teaching, suggestion or incentive supporting the combination." In re Geiger,

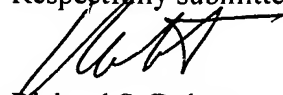
2 U.S.P.Q.2d 1276, 1278 (CAFC 1987). There is no motivation to combine Zakhidov, et al. with Gole, et al; and with the other references to arrive at the instant invention.

The Examiner appears to be going to great lengths to locate and try to interrelate Zakhidov et al. with Gole, et al to form the instant invention, there is no suggestion that they should be combined to form a random nanoporosity on a periodic microporosity. The invention cannot be deemed unpatentable merely because, in a hindsight attempt to reconstruct the invention, one can find elements of it in the art; it must be shown that the invention as a whole was obvious at the time the invention was made without knowledge of the claimed invention. 35 U.S.C. 103. When selective combination of prior art references is needed to make an invention seem obvious, there must be something in the art to suggest that particular combination other than hindsight gleaned from the invention itself, something to suggest the desirability of the combination. Uniroyal, Inc. v. Rudkin-Wiley Corp., 5 U.S.P.Q.2d 1434, 1438 (CAFC 1988). Such a suggestion is absent in the cited references.

The Examiner's approach seems to be to cite a string of references, figuratively throw all the features of the reference teachings in one pot, and then pull out whichever necessary features are needed to reconstruct the claimed invention. Where Applicants' teachings are needed to find the invention, the invention is not obvious. Obviousness is determined at the time the invention is made, not after reading Applicants' teaching. Citing references that merely indicate that individual elements of the claims is not a sufficient basis for a conclusion of obviousness; there must be something that suggests the desirability of combining the references in a manner calculated to arrive at the claimed invention. Ex parte Hiyamizu, 10 U.S.P.Q.2d 1393, 1394 (PTO Bd. Pat. Ap. and Int., 1988).

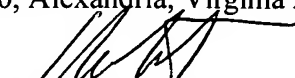
None of the cited references, taken alone or in combination, teaches or suggests the invention claimed by Applicants. For all the above reasons, the are urged to be patentable over the cited references, and the rejections under 35 U.S.C.103 should be overruled.

Respectfully submitted,



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I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail, postage pre-paid in an envelope addressed to Commissioner For Patents; P.O.Box 1450, Alexandria, Virginia 22313-1450, on March 31, 2005.

  
Richard S. Roberts

## IX. APPENDIX

1. A light emitting or light transmitting photonic crystal which comprises a two dimensionally periodic or three dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members having voids between adjacent members, and said members additionally having randomly nanoporous surface porosity and which photonic crystal has a photoluminescence property.
2. The photonic crystal of claim 1 wherein the members comprise spheres.
3. The photonic crystal of claim 1 wherein the members comprise spheres and the average sphere diameter does not exceed about 1000 nm.
4. The photonic crystal of claim 1 wherein the members comprise surfaces or interfaces that are inverse replicas of the surfaces of a monodispersed sphere array, wherein necks exists between neighboring spheres in said sphere array and the average sphere diameter does not exceed about 1000 nm.
5. The photonic crystal of claim 1 wherein the nanoporous surface porosity comprises nanopores having an average pore diameter which is less than about 10 nm.
6. The photonic crystal of claim 1 wherein the members comprise a semiconductor material.
7. The photonic crystal of claim 1 wherein the members comprise silicon.
8. The photonic crystal of claim 1 wherein the members comprise polysilicon.
9. The photonic crystal of claim 1 wherein the members comprise p type or n type doped silicon.

10. The photonic crystal of claim 1 wherein the members comprise p type or n type doped polysilicon.
11. A structure comprising the light emitting or light transmitting photonic crystal of claim 1 positioned on a surface of a substrate.
12. The structure of claim 11 wherein the substrate comprises a material selected from the group consisting of glass, quartz, borosilicate glass, silicon, sapphire and combinations thereof.
13. The structure of claim 11 wherein the substrate comprises sapphire.
14. The structure of claim 11 wherein the substrate comprises sapphire, which substrate is substantially flat, hydrophilic, HF resistant, optically transparent, and resistant to heat elongation in any direction at temperatures of up to about 800 °C.
15. The structure of claim 11 further comprising a device for alternately compressing and expanding the photonic crystal.
16. The structure of claim 11 further comprising a piezoelectric device for alternately compressing and expanding the photonic crystal.
17. The structure of claim 11 further comprising a liquid crystal material that is imbibed on the photonic crystal.
18. (Withdrawn) A process for forming a light emitting or light transmitting photonic crystal which comprises forming a two dimensionally periodic or three dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members having voids between adjacent members, and then providing



surfaces of said members with randomly nanoporous surface porosity and which photonic crystal has a photoluminescence property.

19. (Withdrawn) The process of claim 18 wherein the members comprise spheres.

20. (Withdrawn) The process of claim 18 wherein the members comprise spheres and the average sphere diameter does not exceed about 1000 nm.

21. (Withdrawn) The process of claim 18 wherein the members comprise surfaces or interfaces that are inverse replicas of the surfaces of a monodispersed sphere array, wherein necks exists between neighboring spheres in said sphere array and the average sphere diameter does not exceed about 1000 nm.

22. (Withdrawn) The process of claim 18 wherein the nanoporous surface porosity comprises nanopores having an average pore diameter which is less than about 10 nm.

23. (Withdrawn) The process of claim 18 wherein the members comprise a semiconductor material.

24. (Withdrawn) The process of claim 18 wherein the members comprise silicon.

25. (Withdrawn) The process of claim 18 wherein the members comprise polysilicon.

26. (Withdrawn) The process of claim 18 wherein the members comprise p type or n type doped silicon.

27. (Withdrawn) The process of claim 18 wherein the members comprise p type or n type doped polysilicon.

28. (Withdrawn) The process of claim 18 wherein the members are provided with randomly nanoporous surface porosity by chemical vapor etching, electrochemical etching or chemical stain etching.
29. (Withdrawn) The process of claim 18 wherein the members comprise silicon or polysilicon and the members are provided with randomly nanoporous surface porosity by chemical etching or electrochemical etching in an ethanolic HF solution.
30. (Withdrawn) The process of claim 18 wherein the photonic crystal is positioned on a surface of a substrate.
31. (Withdrawn) The process of claim 30 wherein the substrate comprises a material selected from the group consisting of glass, quartz, borosilicate glass, silicon, sapphire and combinations thereof.
32. (Withdrawn) The process of claim 18 further comprising contacting the photonic crystal with a device for alternately compressing and expanding the photonic crystal.
33. (Withdrawn) The process of claim 18 further comprising contacting the photonic crystal with a piezoelectric device for alternately compressing and expanding the photonic crystal.
34. (Withdrawn) The process of claim 18 further comprising imbibing a liquid crystal material on the photonic crystal.
35. (Withdrawn) A process for the formation of a light emitting or light transmitting three-dimensionally-periodic porous structure, comprising the steps of  
(a) crystallizing spheres of material A into a first structure having three-dimensional periodicity, and voids between spheres, wherein the material A is mechanically and thermally stable to at least about 600° C.,

- (b) treating this first structure so that necks are formed between the spheres of material A,
- (c) infiltrating said first structure with material B to form a A-B composite structure,
- (d) removing material A from said A-B composite structure to form a second structure comprising material B; and then
- e) providing a surface of said second structure with randomly nanoporous surface porosity to thereby produce a structure which has a photoluminescence property.

36. (Withdrawn) A process for preparing a light emitting or light transmitting three-dimensionally-periodic, porous, dielectric, photonic crystalline structure which comprises forming an array of microscopic spheres on a smooth substrate into a face centered cubic structure having spaces between adjacent spheres, which spheres have an average diameter not exceeding about 1000 nm; sintering the spheres under conditions sufficient to attach adjacent spheres to one another by an intermediate neck; forming a solid silicon structure in the spaces between adjacent spheres by infiltrating silane gas into the spaces in a low pressure chemical vapor deposition process; wherein the silane gas is infiltrated into the spaces at a temperature of from about 450 °C to about 600 °C, at a pressure of from about 100 mtorr to about 600 mtorr and at a flow rate of from about 50 sccm/min. to about 150 sccm/min.; removing the spheres; and then providing a surface of said structure with randomly nanoporous surface porosity to thereby produce a structure which has a photoluminescence property.

37. (Withdrawn) The process of claim 36, wherein the opal template in step (a) consists of silica ( $\text{SiO}_2$ ) spheres of diameter from about 100 nm to about 1000 nm.

38. (Withdrawn) The process of claim 36 wherein the nanoporous surface porosity comprises nanopores having an average pore diameter which is less than about 10 nm.

39. (Withdrawn) The process of claim 36, wherein the spheres are surface coated with material a layer of a metal at a thickness of from about 0.1 nm to about 50 nm.

40. (Withdrawn) The process of claim 39 wherein the metal comprises aluminum, gold, silver, platinum, or combinations thereof.
41. (Withdrawn) The process of claim 36, further comprising infiltrating an additional material into the structure in the spaces between adjacent spheres before the removal of the spheres to form a composite structure.
43. (Withdrawn) The process of claim 41 wherein the additional material is selected from the group consisting of thermoelectrics, ferroelectrics, ferromagnets, metals, semimetals, elastomers, polymers and combinations thereof.
44. (Withdrawn) The process of claim 41, wherein the additional material comprises carbon, chalcogenide glasses, tin, lead or combinations thereof.
45. A photonic device which comprises a light emitting or light transmitting photonic crystal which comprises a two dimensionally periodic or three dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members having voids between adjacent members, and said members additionally having randomly nanoporous surface porosity; and an electrically conductive, optically transparent layer positioned on opposite surfaces of the photonic crystal, and which photonic crystal has a photoluminescence property.
46. The photonic device of claim 45 wherein the electrically conductive, optically transparent layers are electrodeposited on the opposite surfaces of the photonic crystal.
47. The photonic device of claim 45 further comprising an electrode attached to the electrically conductive, optically transparent layers.
48. The photonic device of claim 45 further comprising a light emitter positioned to direct light onto the photonic crystal.

49. The photonic device of claim 45 further comprising a light emitter positioned to direct light onto the photonic crystal which is capable of transmitting light having a wavelength in the range of from about 1300 to about 1600 nm.